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The main objective of our research is the modeling, analysis, simulation and estimation of locally stationary signals, time series, data, images, etc. We have made an important advance in the statistical analysis of aerothermal data. We have shown that they fit very well into models of locally power law processes and we have estimated effectively and accurately the structure of the power and the log intercept. Our results are different from those previous analyses had produced and could have quite significant impact in our understanding of laser beam propagation in the atmosphere. The analytical and statistical methods that we use are of general interest and can be used in many other situations where local power law processes arise.

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September 18, 1997

1 Objectives

The main objective of our research is *the modeling, analysis, simulation and estimation* of locally stationary signals, time series, data, images, etc.

2 Status of effort

We spent a lot of time on signal analysis which is applicable to many different remote sensing problems (from seismology to laser propagation in the atmosphere). *We have successfully implemented our theoretical research into a collection of software tools that are effective and sophisticated, yet easy to use.* This is a big advance towards what we had proposed to do. **We have started a new statistical analysis of aerothermal data.** The results so far are very promising and could have considerable impact in many applications, such as the ABL project.

3 Accomplishments and New Findings

- We have made an important advance in the statistical analysis of aerothermal data. We have shown that they fit very well into models of locally power law processes and we have estimated effectively and accurately the structure of the power and the log intercept. Our results are different from those previous analyses had produced and could have quite significant impact in our understanding of laser beam propagation in the atmosphere. The analytical and statistical methods that we use are of general interest and can be used in many other situations where local power law processes arise.

4 Personnel supported

Our ONR grant support partially:
George Papanicolaou, the PI and **Stephane Mallat**.
Knut Solna, graduate student, working on wave propagation and data analysis.

5 Graduate students

I have three Ph.D. thesis students who graduated in June 1997 and one who graduated in June 1996.

Liliana Borcea received her Ph.D. in June 1996. She won an NSF postdoctoral fellowship and spent a year at Caltech. She has a tenure track assistant professorship at Rice University. She is working on network approximations for elliptic equations with high contrast coefficients.

Knut Solna Obtained his Ph.D. in June 1997. He worked on seismic wave propagation. He has analyzed well log data from the North Sea and developed a theory of front propagation in random media. He is working on signal analysis (aerothermal data) with me. He is now at the University of Utah.

Leonid Ryzhik Obtained his Ph.D. in June 1997. He worked on a derivation from first principles of a transport theory for elastic waves in random media. He is at the University of Chicago, on leave to MSRI for a semester.

Ronnie Sircar Obtained his Ph.D. in June 1997. He worked on the effect of program trading on options pricing and on stochastic volatility. He is at the University of Michigan.

I have three continuing Ph.D. students.

Alexei Novikov is a student from Mathematics. He is working on variational principles for nonlinear convection.

Kirsten Boyd is a student from Mathematics working on wavelet methods in signal processing and PDE.

Peter Cotton is a student from Mathematics working on data analysis nonstationary signals and modeling of financial markets.

6 Publications

All papers cited here that have not yet appeared in print can be accessed from http://georgep.stanford.edu (in compressed PostScript format)

Published

- *Diffusion in turbulence*, with Albert Fannjiang, Probability Theory and Related Fields, 105, (1996) pp. 279-334.
- *Localization and mode conversion for elastic waves in randomly layered media*, with B. White and W. Kohler, Wave Motion 23, (1996) pp. 1-22 and 181-201
- *Statistical inversion from reflections of spherical waves by a randomly layered medium*, with M. Asch, M. Postel, B. White and W. Kohler. Waves in Random Media 6, (1996) pp. 293-334.
- *Stability of the P to S energy ratio in the diffusive regime*, L. Ryzhik and J.B.Keller, Bulletin of the Seismological Society of America 86, (1996), pp. 1107-1115.
- *High Contrast Impedance Tomography*, with Liliana Borcea and James Berryman, Inverse Problems 12, (1996), pp. 1-24.
- *Flow past a periodic array of spheres at low Reynolds number*, with Hongwei Cheng, Journal of Fluid Mechanics, 335, 189-212, 1997.
- *Energy transport equations for elastic and other waves in random media*, with L. Rhyzik and J.B.Keller, Wave Motion 24, 327-370, 1996.
- *Motion In A Gaussian Incompressible Flow* , with T. Komorowski, 'The Annales of Applied Probability' 7, (1997), pp. 229-264.

In press

- *Convection enhanced diffusion for random flows*, with Albert Fannjiang, to appear in the Journal of Statistical Physics.
- *Networks for elliptic partial differential equations*, with L. Borcea to appear in the SIAM J. Appl. Math.
- *A hybrid numerical method for high contrast conductivity problems*, with L. Borcea, to appear in the Journal of Computational and Applied Mathematics.
- *Adaptive Covariance Estimation of Locally Stationary Processes* with Stephane Mallat and Zhifeng Zhang, to appear in the 'Annales of Statistics'.
- *General Black-Scholes models accounting for increased market volatility from hedging strategies*, with R. Sircar, to appear in Applied Mathematical Finance.
- *Transport equations for waves in a half space*, with L. Ryzhik and J.B.Keller, to appear in the Communications in PDE.
- *Evolution of trajectory correlations in steady random flows*, with A. Fannjiang and Leonid Ryzhik, to appear in the Lax-Nirenberg anniversary volume published by the AMS.

In refereeing process

- *Self focusing in the perturbed and unperturbed nonlinear Schrödinger equation*, with Gadi Fibich.
- *Waves and Transport*, with Ryzhik. The Park City Lecture Notes.
- *Forward and Markov Approximation: The Strong Intensity Fluctuations Regime Revisited*, with J.P. Fouque, and Y. Samuelides. Submitted to 'Waves in Random Media'.

In preparation

- *Pulse reflection of waves by locally layered random media*, with W. Kohler and B. White. This an extension to *locally* layered random media of our work in SIAM Review in 1991.
- *Pulse spreading by locally layered random media*, with K. Solna.
- *Statistical analysis of aerothermal data*, with K. Solna.
- *Matching pursuit for imaging high contrast conductive media*, with L. Borcea and J. Berryman.
- *The invariant density of a chaotic dynamical system with small noise*, with R. Kuske.

7 Interactions

7.1 Meetings

Lectures at: Meeting on Materials at Penn State, Univ. of South Carolina (ONR-wavelets), Ecole Polytechnique (review of the department), Duke Univ. (mines), Princeton Univ, (students in applied math), Annual meeting of French Numerical Analysts, Annual meeting of Canadian Applied Math Soc., Indiana Univ. special Applied Math meeting, plenary speaker at the biannual meeting of the Brazilian Math Soc., San Antonio meeting on inverse problems, Albuquerque meeting on ABL.

7.2 Consulting

We have extensive collaboration with James Berryman at Livermore. Close collaboration with D. Washburn at Kirtland AFB in connection with the analysis of the ABLEX data. Close collaboration with R.S.Wu (supported by AFOSR Phillips Lab.) at the Tectonics Institute of UC Santa Cruz. Close collaboration with R. Albanese and his colleagues at Brooks AFB on laser-tissue interactions. Close collaboration and regular joint seminars with the Geophysics group of Lane Johnson and Raymond Jeanloz (as well as Philip Stark in Statistics) at UC Berkeley.

I was a member of the DOD Defense Advisory Group on Basic Research (representing Mathematics) and participated in one week review process in April. This was my second year on the TARA pannel.

I was chairman of a committee that reviewed the Mathematics and Computer Science program at ARO.

I collaborate closely with Charles Rino of Vista Research in Mountain View CA on the analysis of aerothermal data from the ABL group at the Phillips Laboratory KAFB.

8 Transitions

I believe, and have received very strong support in lectures and discussions from colleagues and specialists, that the work on the aerothermal data is new and important.

9 Other Grants

My research work is based in the Mathematics Department at Stanford University, which has about 50 Ph.D. students oriented primarily towards theoretical areas. We have a strong Applied Mathematics program in the Mathematics department that amounts to about 20% of resources and activity. I am also a core member of the Scientific Computing and Computational Mathematics Program at Stanford, which is part of the Engineering School and has about 30 Ph.D. students. We need support or partial support for our graduate students, for our postdoctoral and senior visitors that generate momentum for the research effort of our group, for travel to important meetings, and for computing equipment.

Our single investigator, three year NSF grant was renewed in March 1996.

I have continuing support from AFOSR to study waves and diffusion in random media. Recently I got involved with the analysis of the data collected by the Airborne Laser Experiment (ABLEX) at Kirtland AFB.

I am consulting member of a multidisciplinary team of researchers headed by L. Carin (Duke University Electrical Engineering) to study mine detection methods. My contribution will be in the use of acoustic and electromagnetic probing techniques in a complex environment. This project is funded by ARO.

In January 1997 I applied for a five year NSF Group Infrastructure Grant (GIG) for a Mathematical Geophysics Summer School here at Stanford, which was granted: $1.3 for five years. It is a closely coordinated effort with Berkeley and Santa Cruz, as well as Stanford Geophysics, centered around seismic wave probing, imaging and detection. The GIG provides long term support for graduate students, visitors, equipment, etc, but no salary for faculty members.